Predictive Ability of European Heart Surgery Risk Assessment System II (EuroSCORE II) and the Society of Thoracic Surgeons (STS) Score for in-Hospital and Medium-Term Mortality of Patients Undergoing Coronary Artery Bypass Grafting

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Objective: To evaluate the powers of European Heart Surgery Risk Assessment System II (EuroSCORE II) and the Society of Thoracic Surgeons (STS) score in predicting in-hospital and medium-term mortality of patients undergoing coronary artery bypass grafting (CABG).

Methods: Totally 1628 Chinese patients were included between January 2000 and January 2018. Their perioperative clinical data were collected and the patients were closely followed up. According to the length of follow-up time, the total cohort was divided into 1-year, 2-year, 3-year, 4-year and 5-year groups. The in-hospital and medium-term risk prediction of EuroSCORE II and STS score were comparatively assessed by calibration, discrimination, decision curve analysis (DCA), net reclassification index (NRI), integrated discrimination improvement (IDI) and Bland-Altman analysis.

Results: About 36 (2.21%) patients died during hospitalization. Both EuroSCORE II and STS score performed extremely well in predicting in-hospital mortality (area under curve = 0.900 and 0.879, respectively). However, calibration and discrimination analyses showed gradual decrease when these two risk evaluation systems were used to predict mortality during the follow-up period. At the same time, the predictive ability of EuroSCORE II was better than STS score. DCA curves showed that the performances of the two evaluation systems were roughly equal between the threshold probability of 0% to 20%. The percentage of correct reclassification of EuroSCORE II was 21.64% higher than that of STS score in predicting 2-year postoperative mortality. The IDI index showed that the predictive capabilities of these two systems were roughly equivalent. Bland-Altman analysis showed no significant difference between the values of the two systems.

Conclusion: EuroSCORE II and STS score have excellent predictive powers in predicting in-hospital mortality of patients undergoing CABG. In particular, EuroSCORE II is superior in calibration and discrimination. The prediction efficiency of the two risk evaluation systems is still acceptable for two-year postoperative mortality, but decreases year by year.

Keywords: EuroSCORE II, STS score, coronary artery bypass grafting, in-hospital mortality, medium-term prognosis

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Background

The incidence of coronary atherosclerotic heart diseases is consistently increasing.[1] At the same time, the operation number of coronary artery bypass grafting (CABG) in China has increased dramatically.[2,3] Hence, evaluation of surgical risks and prognosis of patients before operation becomes increasingly important, and is very critical in selecting surgical cases, grasping surgical indications, and preoperative conversations.[4,5] European Heart Surgery Risk Assessment System II (EuroSCORE II)[6] and the Society of Thoracic Surgeons (STS) score[7] are widely used in preoperative risk assessment of cardiac operation. They are a part of routine treatment in many heart centers.[8,9] The original intentions are to identify high-risk patients who will die during hospitalization and predict their postoperative mortality. In recent years, some scholars find these evaluation systems practically valuable in predicting postoperative complications, hospitalization costs, and long-term prognosis.[10–16] This study is aimed to explore the abilities of EuroSCORE II and STS score on predicting the in-hospital and medium-term prognosis of patients undergoing CABG.

Methods

Patients

Between January 2000 and January 2018, 1732 consecutive patients who underwent isolated CABG in the department of cardiovascular surgery were included. The exclusion criteria were lack of perioperative data (21, 1.21%), non-first cardiac operation (5, 0.29%), and lack of follow-up data (88, 5.08%). In the end, 1628 patients were included in this database (Figure 1).

All patients underwent CABG surgery, and their immediate family members were aware of the operative risks and signed consents form before the surgery. Detailed perioperative clinical data were obtained from the hospital electronic information system. All patients were followed up after the operation, and the follow-up data was registered. Before operation, the risk scores of each patient were calculated based on EuroSCORE II and STS score. Before discharge from the hospital, residents educated each patient and made an appointment for review.

This study which as a retrospective cohort study was approved by the ethics committee of the first Affiliated hospital of Nanjing Medical University with the serial number 2017SR053. The trial was registered at http://www.chictr.org.cn, with registration number ChiCTR2000032365. This study was conducted in accordance with the Declaration of Helsinki.

Outcome Endpoint

Primary endpoint was in-hospital mortality, which was defined as any death within 30 days after operation or during postoperative hospitalization. Secondary endpoint was mortality during the follow-up period, which referred to all-cause death during the follow-up period.

Follow-Up

The patients from the total cohort were followed up via telephone or outpatient service by specially-designated investigators in the first, third and sixth months after the operation and then once a year. If the conditions of a patient changed, he/she was recommended to go to the clinic in time. According to the length of follow-up time, the total cohort was divided into 1-year, 2-year, 3-year, 4-year and 5-year groups. Patients who were followed up for more than 12 months or who died during the 1-year follow-up period were included in the 1-year group. If a patient was lost to follow-up within one year after operation, he/she was excluded from the 1-year group. The same method was used to construct the other four groups.

Statistical Analysis

Continuous data were expressed as mean ± standard deviation (normal distribution) or median and interquartile ranges (non-normal distribution), and compared between groups through Student's *t*-test or Mann–Whitney *U*-test. Categorical variables were presented as number and percentage and compared using Fisher's exact or Chi-square tests.

EuroSCORE II and STS score were calibrated by Hosmer–Lemeshow (H-L) goodness-of-fit statistic[17] and calibration plot. Discrimination was assessed by C statistics using the area under receiver's operating characteristic curve (AUC).[18] $P < 0.05$ suggests good calibration, meaning the risk evaluation system predicts mortality more accurately. AUC of 0.50–1.00, and AUC > 0.70, > 0.75, and > 0.80 indicate the discrimination is available, good and excellent, respectively.

The net benefits of the two risk evaluation systems for predicting in-hospital and medium-term mortality were measured by decision curves analysis (DCA).[19] The proportion of all false positive patients was subtracted by DCA from the proportion of true positive patients, and then weighted according to the relative harm of false positive and false negative results.

Consistency of the two evaluation systems in predicting in-hospital and medium-term mortality was tested by the net reclassification index (NRI).[20] Patients were divided into two groups by different standards. A change into a higher or a lower group means upward or downward movement respectively.

Integrated discrimination improvement (IDI)[21] which considers the situation of different cut points can reflect the overall improvement of the model and slightly complement the shortcomings of NRI. At the same time, IDI also makes up for the shortcomings of AUC, and can vividly show the proportion of research objects that are accurately re-identified. IDI reflects the change in the prediction probability gap between the two risk evaluation systems. IDI is calculated based on the prediction probability for each individual as follows:

$$IDI = \left(P_{new,events} - P_{old,events}\right) - \left(P_{new,non\_events} - P_{old,non\_events}\right)$$

where $P_{new,events}$ is the average value of the new risk evaluation system in predicting the probability of disease occurrence for each individual in the patient group, and the subtraction of the two averages represents the amount of change in the prediction probability. A larger IDI means a better predictive ability of the risk evaluation system.

Agreement between the two risk evaluation systems was estimated by Bland-Altman analysis.[22] The predictive mortality was calculated by the two systems separately. Figures were plotted by the differences between the two sorts of predictive mortalities and the mean between them. All differences equal to 0 indicate the two systems fully agree with each other. The agreement interval was calculated using the mean of differences ± standard deviation. Over 95% of the points fall in the agreement interval, which indicates a good agreement between the two risk evaluation systems.

Statistical analysis was performed on SPSS 23.0 for Windows (IBM, Chicago, USA). DCA was performed on R software 3.4.0 with the package Decision curve. Two-sided $P \leq 0.05$ was considered as the significant level.

Results

Totally 1628 patients were eventually included. The median age was 65.00 (11.00) years. The numbers (proportions) of females, morbid obesity, diabetes, hypertension, renal failure, pulmonary hypertension, three-vessel disease, urgent surgery and cardiopulmonary bypass are 394 (24.22%), 88 (5.42%), 536 (32.91%), 1119 (68.73%), 26 (1.60%), 153 (9.39%), 1444 (88.72%), 47 (2.88%) and 348 (21.9%) respectively. Totally 36 (2.21%) patients died during hospitalization.

The total cohort was divided into a death group and a survival group. Baseline clinical characteristics of the patients were shown in Table 1. The death group versus the survival group showed older age (72.00 vs 65.00 years) and higher proportions of females (52.82% vs 23.61%), diabetes (55.62% vs 32.40%), renal failure (22.18% vs 1.12%), peripheral vascular disease (5.67% vs 2.12%), previous percutaneous coronary intervention (PCI) treatment (16.71% vs 5.92%), myocardial infarction (36.10% vs 13.30%), pulmonary hypertension (16.60% vs 9.34%), salvage surgery (13.92% vs 0.28%), cardiopulmonary bypass (30.61% vs 21.90%), but less morbid obesity (2.81% vs 5.51%).

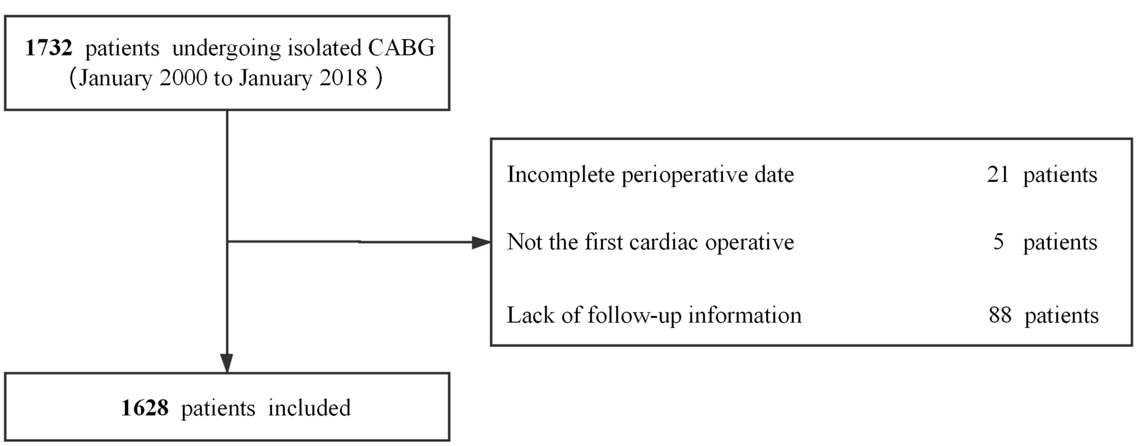

Figure 1 Flow chart of patient enrollment.

The 5-year group versus the 1-year group demonstrated higher proportions of renal failure (1.22% vs 0.62%), previous PCI treatment (5.50% vs 3.32%), pulmonary hypertension (14.80% vs 2.54%), butless cardiopulmonary bypass (22.60% vs 31.90%). However, other factors were not significantly different between the two groups (Table 2).

Calibration

The H-L goodness-of-fit statistic was used to verify the calibration of the two risk evaluation systems. When the two systems predicted the in-hospital mortality of CABG-treated patients, the predicted mortality rate and the actual mortality rate agreed well (P>0.05). However, both systems performed poorly in predicting medium-term mortality. The calibration of EuroSCORE II was acceptable only in predicting mortality of the 4-year postoperative follow-up (Table 3).

Certainly, the calibration chart can show those results more intuitively. For the mortality in the follow-up period, the deviation between the fitted regression line and the reference line was large (Figure 2).

Discrimination

AUC can objectively display and compare the discrimination of risk evaluation systems. The two risk evaluation systems both performed extremely well in predicting in-hospital mortality (AUC of 0.900 and 0.879, respectively). However, the predictive abilities gradually decreased when these two risk evaluation systems were used to predict the mortality during the follow-up period. The prediction of mortality in 2-year follow-up was excellent, and became available in the 4-year follow-up. At the same time, the predictive ability of EuroSCORE II was better than STS score (Figure 3, Table 3).

All-cause death was of great concern. Cardiogenic death was defined as death due to heart disease during the follow-up period. EuroSCORE II and STS score showed better ability in predicting cardiogenic death during follow-up period than all-cause death. Similarly, the predictive ability became worse with the extension of follow-up time (Table 4).

DCA Curve

The DCA curve can visually display the clinical net benefits of the risk evaluation systems under certain threshold probability. In general, the performances of the two risk evaluation systems are roughly equal between threshold probability 0 and 20%, regardless of the mortality at postoperative 1-year, 2-year, 3-year, 4-year or 5-year follow-up. Surprisingly, STS score shows higher clinical net benefit than EuroSCORE II within the threshold probability of 0 to 15%. This seems to be contrary to the results of discrimination and calibration when predicting in-hospital mortality. Within the threshold probability of 15% to 20%, EuroSCORE II shows higher clinical net benefit than STS score (Figure 4).

NRI Index

The cut-off value of each subgroup was determined according to the ROC curve. All values of NRI are negative in each subgroup, which means negative improvement. The predictive ability of STS score in predicting 2-year postoperative mortality is reduced when compared with EuroSCORE II, whether it is all-cause death (−21.64%, P=0.026) or cardiogenic death (−24.14%, P=0.028). Differences between these two risk evaluation systems in the remaining subgroups are not significant (P>0.05) (Table 5).

IDI Index

A larger IDI indicates a better predictive ability of the new model. STS score has worse predictive ability than EuroSCORE II in predicting in-hospital mortality. STS score also performs poorly in predicting 2-year, 4-year and 5-year postoperative mortality (−0.32%, −0.24%, −0.26%, respectively). The decrease in predictive ability of STS score is not obvious. Details can be obtained from Table 5.

Bland-Altman Analysis

About 95% of the differences between the values of the two risk evaluation systems fall within the value range described by the 95% consistency limit. These results show no significant difference between the values of the two systems in predicting mortalities in different periods (Figure 5).

Discussion

These two risk evaluation systems can well predict in-hospital mortality and 2-year postoperative death in Chinese patients undergoing CABG. The in-hospital mortality of patients undergoing CABG is roughly equivalent to the rates in developed countries.[23,24] EuroSCORE II outperforms STS score in predicting either in-hospital mortality or mortality during the follow-up period. The predictive powers of these two risk evaluation systems declined year by year in predicting mortality during follow-up periods. This phenomenon also occurred when

Table 1 Baseline Clinical Characteristics of the Whole Cohort and Subgroups

Risk Factors	Total (n = 1628)	Death (n=36)	Survival (n=1592)	*P*
Age (y)	65.00(11.00)	72.00(11.00)	65.00(11.00)	<0.001*
Female (n, %)	394(24.22)	19(52.82)	375(23.61)	<0.001*
Weight (kg)	69.00(13.00)	61.00(13.00)	69.00(14.00)	0.001*
Height (cm)	168.00(12.00)	168.00(12.00)	168.00(12.00)	0.108
BMI (kg/m^2)	24.69(3.81)	23.77(3.79)	24.74(3.84)	0.022*
Morbid obesity (n, %)	88(5.42)	1(2.81)	87(5.51)	0.048*
Body surface area (m^2)	1.86(0.21)	1.75(0.20)	1.86(0.20)	0.301
Diabetes (n, %)	536(32.91)	20(55.62)	516(32.40)	0.043*
Hypertension (n, %)	1119(68.73)	26(72.22)	1093(68.70)	0.320
Renal failure (n, %)	26(1.60)	8(22.18)	18(1.12)	<0.001*
Serum creatinine (μmol/l)	77.60(25.68)	98.42(25.88)	77.03(25.85)	<0.001*
Ccr (mL/min)	77.21(32.32)	50.71(32.38)	78.12(32.04)	<0.001*
Stroke (n, %)	62(3.78)	3(8.31)	59(3.73)	0.071
COPD (n, %)	37(2.29)	0(0.00)	37(2.33)	0.058
Peripheral vascular disease (n, %)	35(2.06)	2(5.67)	33(2.12)	0.006*
Previous PCI treatment (n, %)	100(6.10)	6(16.71)	94(5.92)	<0.001*
Atrial flutter and fibrillation (n, %)	51(3.12)	1(2.81)	50(3.10)	0.804
Pulmonary hypertension (n, %)	153(9.39)	6(16.60)	147(9.34)	<0.001*
Myocardial infarction (n, %)	225(13.78)	13(36.10)	212(13.30)	<0.001*
Unstable angina pectoris (n, %)	863(53.30)	16(44.42)	847(53.20)	0.109
Number of diseased vessels (n)	3.00(0.00)	3.00(0.00)	3.00(0.00)	0.052
Three-vessel coronary disease (n, %)	1444(88.72)	26(72.22)	1418(89.07)	0.023*
NYHA IV (n, %)	30(1.81)	6(16.71)	24(1.52)	0.744
LVEF (%)	63.00(6.50)	52.91(6.30)	63.00(6.20)	<0.001*
Preoperative IABP (n, %)	12(0.70)	0(0.00)	8(0.52)	<0.001*
Status of surgery				
Elective (n, %)	1574(96.52)	28(77.81)	1543(96.91)	0.042*
Urgent (n, %)	47(2.88)	3(8.32)	44(2.81)	<0.001*
Salvage (n, %)	10(0.59)	5(13.92)	5(0.28)	<0.001*
Number of grafts (n)	3.00(1.00)	3.00(1.00)	3.00(1.00)	0.064
Cardiopulmonary bypass (n, %)	348(21.9)	11(30.61)	348(21.90)	0.034*
EuroSCORE II	1.32(1.08)	4.32(5.89)	1.30(1.04)	<0.001*
STS score	0.74(0.73)	3.03(2.55)	0.73(0.70)	<0.001*

Note: *Represented that the difference between the survival group and the death group was statistically significant.
Abbreviations: BMI, body mass index; Ccr, endogenous creatinine clearance rate; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; NYHA, New York heart association; LVEF, left ventricular ejection fraction; IABP, intra-aortic balloon pump; EuroSCORE II, European Heart Surgery Risk Assessment System II; STS, the Society of Thoracic Surgeons.

these two risk evaluation systems predicted cardiogenic mortality.

Compared with other surgical procedures, CABG surgery is characteristic of high risk and high mortality.[25] Therefore, effective surgical risk evaluation of patients before operation has important clinical application value. This is very beneficial for identifying risks in advance and for choosing appropriate treatment options. To achieve this goal, scholars worldwide have made unremitting efforts. According to incomplete statistics, there are hundreds of risk evaluation systems related to cardiovascular surgery.[26–28] EuroSCORE II and STS score are two of the most influential and widely-used risk evaluation systems in the field of cardiovascular surgery.[8] EuroSCORE was originally a quantitative risk evaluation system to predict in-hospital mortality after cardiovascular operation.[29] After continual updating, the latest version is EuroSCORE II.[6] STS score is also widely used in North America.[7] STS score is an online calculation tool based on the Heart Surgery Database of the Society of Thoracic Surgeons. These two risk evaluation systems have strong ability in predicting in-hospital mortality[4,9,30] and show

Table 2 Baseline Clinical Characteristics of Subsets Divided According to the Length of Follow-Up

Risk Factors	PFU of 1 Year (n = 1476)	PFU of 2 Years (n = 1356)	PFU of 3 Years (n = 1162)	PFU of 4 Years (n = 872)	PFU of 5 Years (n = 788)
Age (y)	65.00(11.00)	65.00(11.00)	65.00(11.00)	66.00(11.00)	65.00(11.00)
Female (n, %)	351(23.80)	327(24.10)	278(23.89)	218(25.01)	194(24.64)
Weight (kg)	69.00(14.00)	69.00(14.00)	69.00(14.00)	69.00(14.00)	69.00(14.00)
Height (cm)	168.00(12.00)	168(12.00)	168.00(12.00)	168.00(12.00)	168.00(12.00)
BMI (kg/m^2)	24.73(3.85)	24.76(3.88)	24.74(3.84)	24.69(3.85)	24.73(3.84)
Morbid obesity (n, %)	83(5.60)	81(6.00)	66(5.70)	48(5.51)	44(5.61)
Body surface area (m^2)	1.86(0.21)	1.86(0.21)	1.86(0.21)	1.86(0.21)	1.86(0.20)
Diabetes (n, %)	478(32.40)	435(32.10)	379(32.61)	295(33.81)	266(33.80)
Hypertension (n, %)	1020(69.10)	942(69.50)	807(69.38)	629(72.10)	580(73.60)
Renal failure (n, %)	18(1.22)	17(1.31)	12(0.99)	10(1.11)	5(0.62)
Serum creatinine (μmol/l)	77.50(25.60)	77.45(25.75)	78.00(26.70)	79.10(25.80)	79.90(25.85)
Ccr (mL/min)	78.03(31.39)	77.89(32.75)	76.85(33.31)	76.30(32.20)	76.23(32.04)
Stroke (n, %)	55(3.71)	48(3.53)	35(2.95)	24(2.80)	24(2.98)
COPD (n, %)	34(2.30)	30(2.22)	23(1.96)	15(1.71)	15(1.91)
Peripheral vascular disease (n, %)	29(2.00)	24(1.81)	24(2.11)	16(1.79)	15(1.91)
Previous PCI treatment (n, %)	81(5.50)	71(5.20)	53(4.58)	30(3.41)	26(3.32)
Atrial flutter and fibrillation (n, %)	46(3.12)	40(2.90)	33(2.75)	26(2.97)	24(2.93)
Pulmonary hypertension (n, %)	125(14.80)	110(8.11)	89(7.59)	31(3.57)	20(2.54)
Myocardial infarction (n, %)	200(13.62)	175(12.89)	153(13.21)	124(14.17)	117(14.80)
Unstable angina pectoris (n, %)	788(53.40)	746(55.01)	628(53.87)	472(54.09)	430(54.60)
Number of diseased vessels (n)	3.00(0.00)	3.00(0.00)	3.00(0.00)	3.00(0.00)	3.00(0.00)
Three-vessel coronary disease (n, %)	1319(89.97)	1206(88.93)	1040(89.50)	776(88.99)	695(88.23)
NYHA IV (n, %)	23(1.61)	19(1.41)	14(1.20)	12(1.36)	11(1.39)
LVEF (%)	63.00(6.60)	63.00(6.80)	63.00(6.80)	63.00(6.10)	63.00(6.20)
Preoperative IABP (n, %)	6(0.41)	5(0.37)	4(0.31)	2(0.21)	2(0.26)
Status of surgery					
Elective (n, %)	1434(97.2)	1314(96.89)	1121(96.48)	860(98.62)	778(98.77)
Urgent (n, %)	37(2.51)	37(2.71)	36(3.09)	10(1.12)	9(1.12)
Salvage (n, %)	5(0.31)	5(0.36)	5(0.41)	2(0.20)	1(0.11)
Number of grafts (n)	4.00(1.00)	3.00(1.00)	3.00(1.00)	3.00(1.00)	3.00(1.00)
Cardiopulmonary bypass (n, %)	333(22.60)	318(23.50)	303(26.09)	274(31.30)	251(31.90)

Abbreviations: PFU, postoperative follow-up; BMI, body mass index; Ccr, endogenous creatinine clearance rate; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; NYHA, New York heart association; LVEF, left ventricular ejection fraction; IABP, intra-aortic balloon pump.

the same good results in the present study. With the widespread application of these two systems in cardiovascular surgery, clinicians hope to expand their scopes of application. Some scholars believe these two systems are useful in predicting postoperative complications, hospitalization costs, ICU retention time, and even medium- and long-term prognosis.[13,14,31]

The surgical risk evaluation system is a quantitative tool for preoperative assessment of operative risks. Many factors affect its predictive performance, and the risk evaluation system of different operations will also differ.[4] In a previous clinical observational study, we found that EuroSCORE II could improve the prediction of in-hospital death in patients with off-pump CABG after integrating preoperative myocardial injury marker.[32] Another previous study demonstrates that peak and peak time occurrences of perioperative myocardial injury markers are related to mid-term outcomes.[33] The short-term, mid-term, and long-term prognosis outcomes after operation are affected by disease characteristics, treatment methods, underlying diseases, age, and even gender, which are very complicated.[3] Like the "butterfly effect", subtle differences among patients can also lead to different long-term prognosis outcomes. Thus, broadening the application scope of the risk evaluation systems should be cautious. These two risk evaluation systems may contain some

Table 3 The in-Hospital and Medium-Term All-Cause Mortality of EuroSCORE II and STS Score

		Total	PFU of 1 Year	PFU of 2 Years	PFU of 3 Years	PFU of 4 Years	PFU of 5 Years
Number of patients		1628	1476	1356	1162	872	788
Death		36	21	32	46	52	61
Mortality (%)		2.21	1.42	2.36	3.96	5.96	7.74
EuroSCORE II	Value	1.315 (1.078)	1.300(1.040)	1.300(1.040)	1.340(1.022)	1.400(1.090)	1.430(1.108)
	AUC	0.900	0.759	0.786	0.731	0.708	0.698
	H–L statistics	0.071	0.006	0.001	0.001	0.111	0.041
STS score	Value	0.744 (0.732)	0.732(0.719)	0.732(0.712)	0.749(0.513)	0.785(0.263)	0.796(0.749)
	AUC	0.879	0.746	0.760	0.720	0.697	0.689
	H–L statistics	0.104	0.289	0.028	0.032	0.012	0.154

Abbreviations: PFU, postoperative follow-up; EuroSCORE II, European system for cardiac operative risk evaluation II; AUC, area under receiver operating characteristic curve; H–L statistics, Hosmer-Lemeshow statistics; STS, score, the Society of Thoracic Surgeons score.

factors that affect long-term prognosis. As the follow-up time is prolonged, however, other factors may play a more important role. It is unrealistic to use only one risk evaluation system to solve all clinical problems.

EuroSCORE II and STS score both can also accurately predict the prognosis of Chinese patients undergoing CABG.[30] In this study, EuroSCORE II and STS score are both superior in predicting in-hospital mortality. This result once again proves the strong adaptability and popularization of these two widely-used risk evaluation systems. The present study shows that the two systems have potential

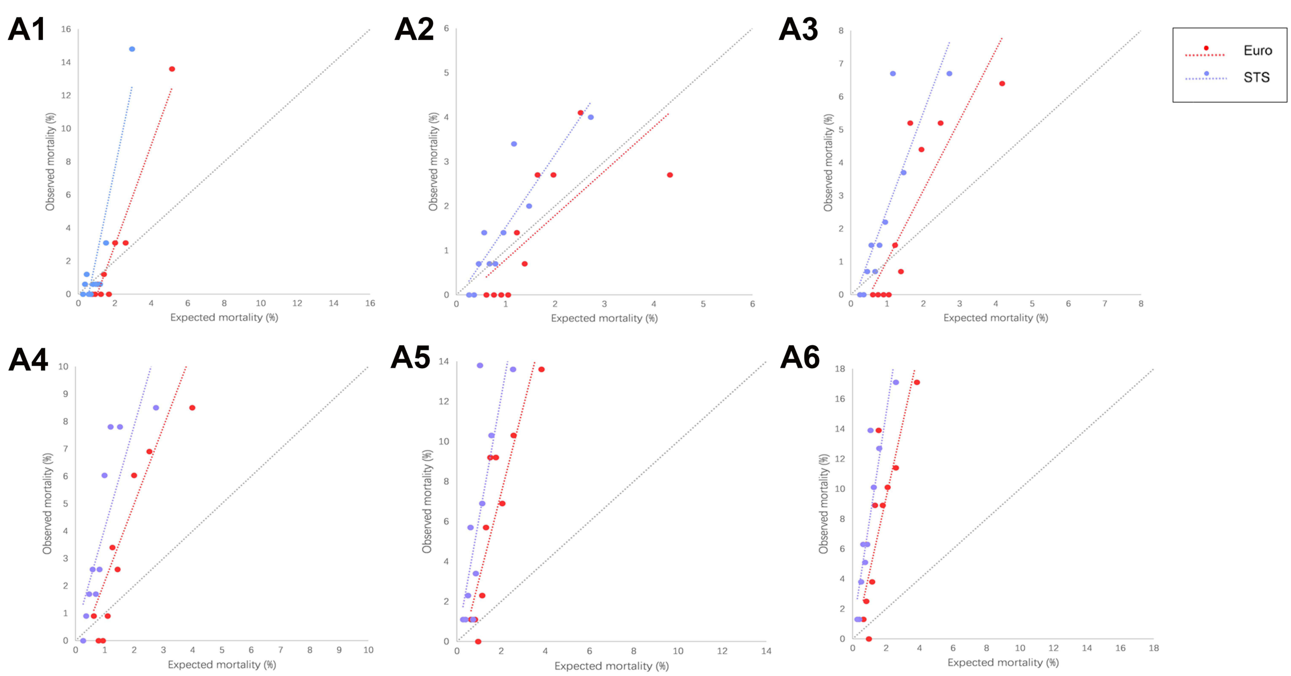

Figure 2 Calibration curves between EuroSCORE II and STS score. Scatter plots were drawn with the actual mortality of each group as the dependent variable (Y) and the expected mortality rate as the independent variable (X), and the regression line was fitted. The slope of the reference line (gray dotted line) is 1 and the intercept is 0. If the fitted straight line is closer to the reference line, the calibration of the corresponding risk evaluation system is higher. (**A1**–**A6**) calibration curves in predicting in-hospital, postoperative one-year, two-year, three-year, four-year and five-year mortality rates respectively.

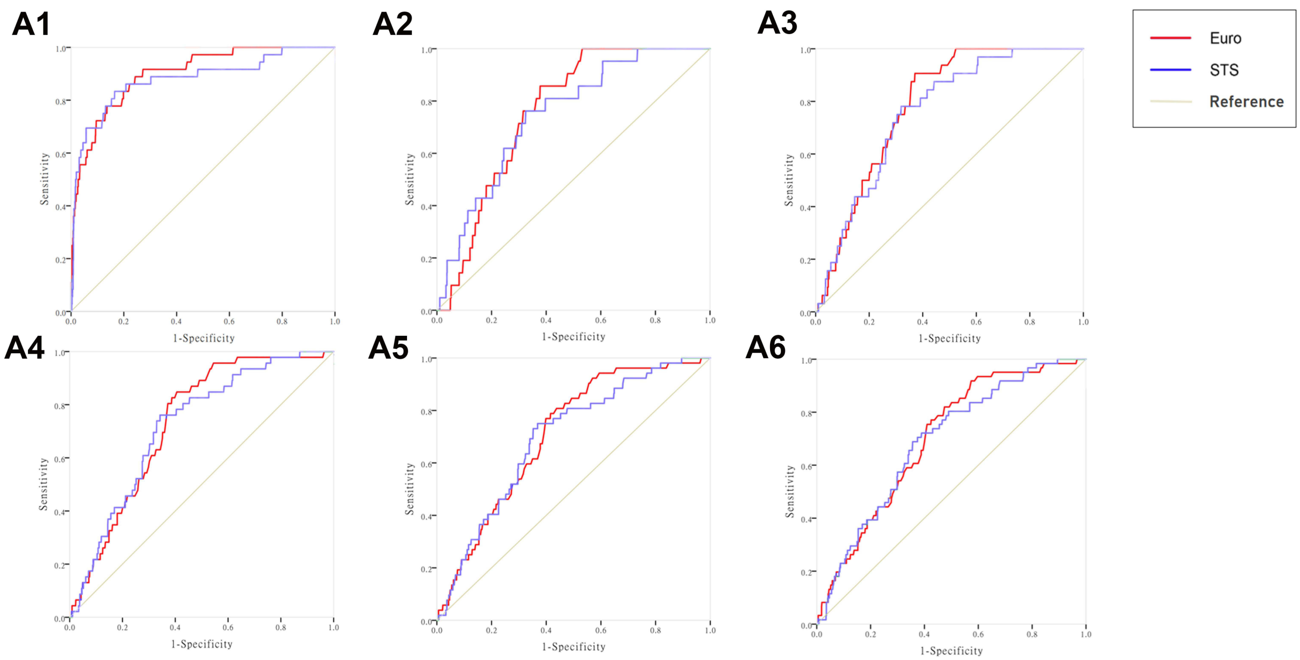

Figure 3 ROC curves of EuroSCORE II and STS score. (**A1**–**A6**) ROC curves of predicting in-hospital, postoperative one-year, two-year, three-year, four-year and five-year mortality rates respectively.

predictive powers for mid-term prognosis. However, EuroSCORE II and STS score are only based on preoperative clinical data to calculate the scores of patients undergoing cardiovascular operation. More postoperative risk factors are needed to predict the long-term prognosis of patients. In short, any risk evaluation system is only effective for a specific outcome or a specific time period, and cannot be a panacea. Thus, a new risk evaluation system involving more postoperative factors must be established.

An interesting phenomenon exists in the total cohort that there is less morbid obesity in the death group

Table 4 The Medium-Term Cardiogenic Mortality of EuroSCORE II and STS Score

		PFU of 1 Year	PFU of 2 Years	PFU of 3 Years	PFU of 4 Years	PFU of 5 Years
Number of patients		1476	1356	1162	872	788
Postoperative follow-up cardiogenic death		14	20	27	30	34
Postoperative follow-up cardiogenic mortality (%)		0.95	1.47	2.32	3.44	4.31
EuroSCORE II	Value	1.300(1.040)	1.300(1.040)	1.340(1.022)	1.400(1.090)	1.430(1.108)
	AUC	0.778	0.805	0.752	0.742	0.739
	H–L statistics	0.083	0.025	0.034	0.205	0.069
STS score	Value	0.732(0.719)	0.732(0.712)	0.749(0.513)	0.785(0.263)	0.796(0.749)
	AUC	0.778	0.788	0.753	0.726	0.728
	H–L statistics	0.378	0.060	0.041	0.012	0.020

Abbreviations: PFU, postoperative follow-up; EuroSCORE II, European system for cardiac operative risk evaluation II; AUC, area under receiver operating characteristic curve; H–L statistics, Hosmer-Lemeshow statistics; STS score, the Society of Thoracic Surgeons score.

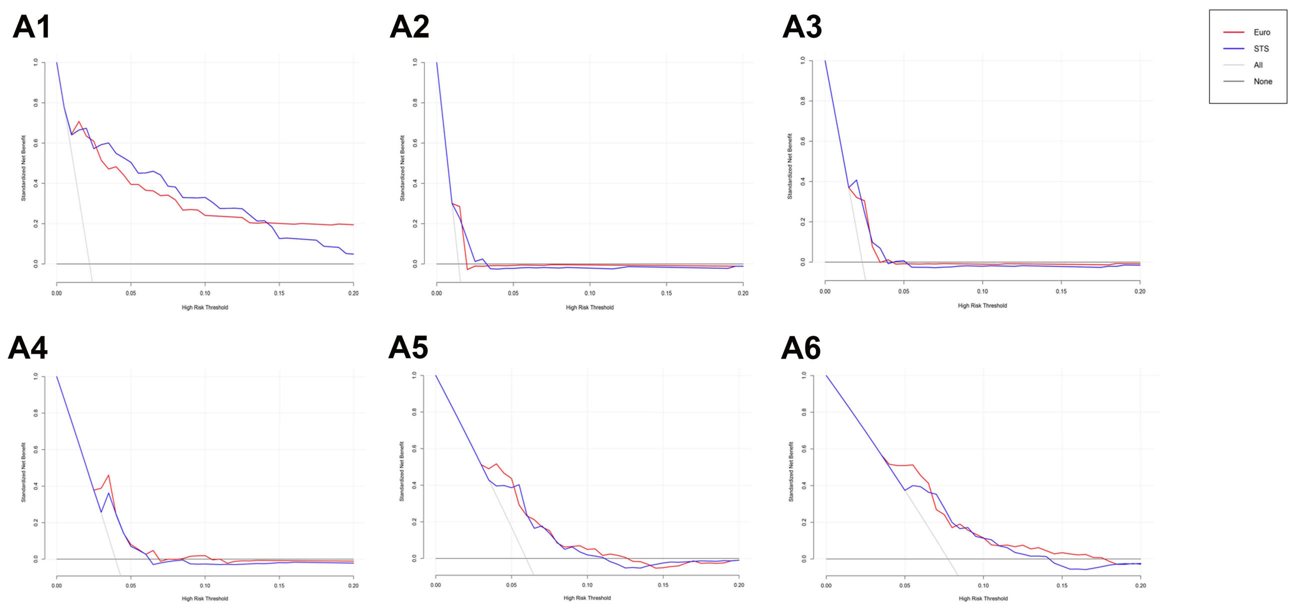

Figure 4 Decision curve analysis of EuroSCORE II and STS score. The gray line represents the net benefits of providing surgery for all patients, assuming that all patients would survive. The black line represents the net benefits of surgery to no patients, assuming that none would survive after operation. The red and blue lines stand for the net benefits of applying surgery to patients according to EuroSCORE II and STS score respectively. (**A1**–**A6**) DCA curves of predicting in-hospital, postoperative one-year, two-year, three-year, four-year and five-year mortality rates respectively.

compared with the survival group (2.81% vs 5.51%). Our previous study reported a similar phenomenon[34] that the risk of in-hospital mortality after operation decreased with the increase of body mass index (BMI). BMI has a significant independent protective effect on in-hospital mortality after operation, and this protective effect is more significant in patients receiving off-pump coronary artery bypass. In the present study, patients in the survival group have higher BMI than the death group (24.74 vs 23.77kg/m^2, *P*=0.022).

Table 5 NRI and IDI of EuroSCORE II and STS Score in Predicting in-Hospital and Medium-Term Mortality

EuroSCORE II vs STS Score		**NRI**			**IDI**		
		Value (%)	**95% CI**	***P***	**Value (%)**	**95% CI**	***P***
In-hospital death		−9.19	−21.45~3.07	0.142	−2.66	−4.31~1.02	0.001*
PFU of 1 year	All-cause death	−16.77	−40.96~7.42	0.174	−0.06	−0.38~0.25	0.696
	Cardiogenic death	−19.15	−44.33~6.03	0.136	−0.08	−0.48~0.32	0.692
PFU of 2 years	All-cause death	−21.64	−40.64~-2.64	0.026*	−0.32	−0.63~-0.01	0.044*
	Cardiogenic death	−24.14	−45.71~-2.56	0.028*	−0.40	−0.86~0.05	0.081
PFU of 3 years	All-cause death	−11.86	−27.59~3.87	0.139	−0.25	−0.5~0	0.055
	Cardiogenic death	−13.23	−33.42~6.96	0.199	−0.26	−0.61~0.09	0.151
PFU of 4 years	All-cause death	−11.04	−25.75~3.67	0.141	−0.24	−0.47~-0.01	0.039*
	Cardiogenic death	−15.53	−34.97~3.91	0.117	−0.29	−0.61~0.03	0.077
PFU of 5 years	All-cause death	−9.16	−22.47~4.15	0.177	−0.26	−0.46~-0.05	0.015*
	Cardiogenic death	−10.70	−28.32~6.91	0.234	−0.29	−0.58~0	0.051

Notes: *Represented that the difference between EuroSCORE II and STS score was statistically significant. Think of EuroSCORE II as an old model, and STS score as a new model.

Abbreviations: NRI, net reclassification index; IDI, integrated discrimination improvement; PFU, postoperative follow-up; CI, Confidence interval.

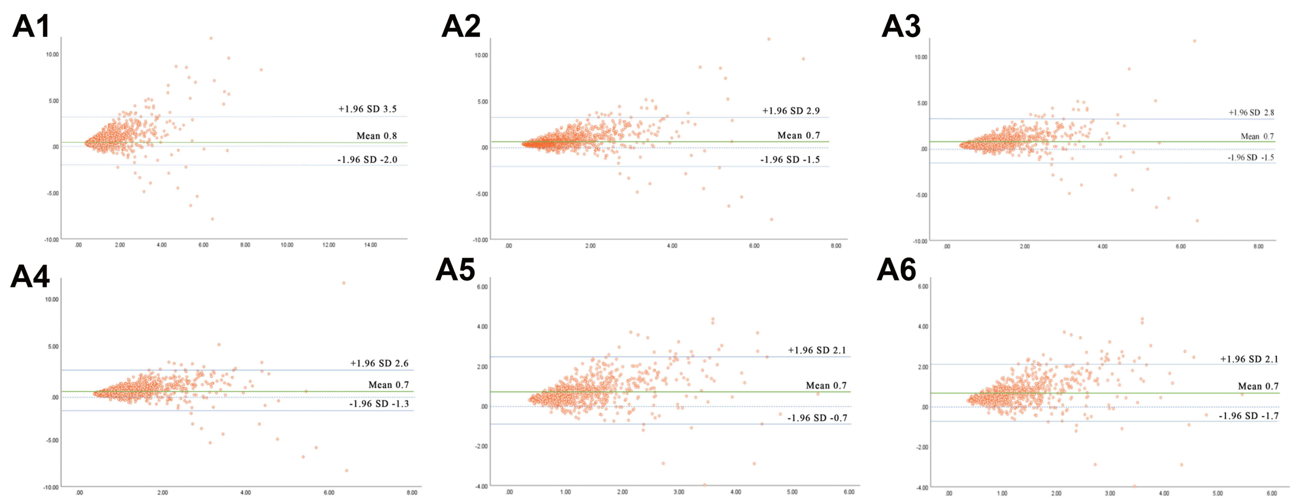

Figure 5 Bland-Altman plots between EuroSCORE II and STS score. The green line represents the mean of the difference between the two risk evaluation systems. The blue line represents the 95% confidence interval. (**A1**–**A6**) Bland-Altman plots of predicting in-hospital, postoperative one-year, two-year, three-year, four-year and five-year mortality rates respectively.

Limitations

Firstly, the time span of this study was up to 18 years, and the follow-up time was also long. During this long period, cardiac surgery techniques, instruments and treatment concepts have all greatly progressed, which will obviously change the prognosis of patients. These factors may have caused the selection bias. Secondly, during the follow-up, some cases were lost to follow-up, which would also lead to bias. Finally, in this single-center study, the research results can be hardly expanded to the outside, verification of which requires more multi-center prospective studies.

Conclusions

EuroSCORE II and STS score have excellent predictive ability for in-hospital mortality after CABG and the its predictive ability for two years after CABG is also satisfactory. However, with the extension of follow-up period, the mortality predictive ability is gradually decreased. Therefore, the application of these two risk evaluation systems to predict medium-term prognosis after cardiovascular operation requires further verification.

Data Sharing Statement

If readers need complete original data, they can contact the corresponding author (Dr. Zhi Li) to obtain it.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the first Affiliated hospital of Nanjing Medical University (2017SR053) and registered with the number of ChiCTR2000032365 (http://www.chictr.org.cn/). This study was conducted in accordance with the Declaration of Helsinki. All patients included in the study, or their legal representatives, signed written informed consents to participate in the study.

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Disclosure

The authors declare that they have no competing interests.

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